10

RELIABILITY, AVAILABILITY, AND MAINTAINABILITY[1]

Reliability and Maintainability are Force Effectiveness Multipliers.
Key concept

10.1 INTRODUCTION

Reliable systems result in increased combat capability while requiring fewer spare parts and personnel. Maintainable systems require fewer people and specialized skills; it also reduces maintenance times. These reductions result in lower ownership costs. The advantages go beyond the system itself. Large, complex combat support structures are vulnerable to attack. Reliable systems mean reduced dependence on airlift and pre-positioning. This chapter will discuss policies, definitions, requirements, processes, and techniques. The contents are intended to give the reader an understanding of these policies and procedures, which are used for design of developmental systems and procurement of commercial items.

10.2 RELIABILITY, AVAILABILITY, AND MAINTAINABILITY (RAM) POLICY (DOD 5000.2-R)

RAM issues should be addressed early in the acquisition cycle to meet operational requirements and to reduce life-cycle costs. These RAM issues should be stated in quantifiable operational terms that are measurable during testing. Derive from this what you need to support system readiness objectives.

- Reliability requirements address both mission reliability and logistics reliability.
- Availability requirements address readiness of the system.
- Maintainability requirements address servicing, preventive, and corrective maintenance.

The PM plans and executes the designing, manufacturing, and testing activities that demonstrate the system's performance prior to production(s) and reflect a mature design.

10.3 RELIABILITY, AVAILABILITY, AND MAINTAINABILITY OVERVIEW

[1] Sections 10.1 through 10.5.4 are based on the contents of a DSMC Teaching Note prepared by Professor Mark Fantasia, Logistics Management Department, March 1997. The Teaching Note, in turn, is a compilation of hundreds of pages from different sources.

10.3.1 The purposes of the DoD RAM (DoD 5000.2-R) are to:

- increase combat capability/effectiveness through:
  - "user" or operator measures by system utilization, operational readiness/availability, and mission success, and
  - mission reliability definition; and

- reduce life-cycle ownership costs through:
  - maintenance manning, and
  - logistics support.

Commonly Asked Questions:

What is Reliability and Maintainability (R&M)? Why is it important?

How do we quantify R&M and its effects?

How much R&M is needed, and what can we expect?

How do we design R&M into hardware and software?

How do manufacturing processes affect R&M?

How do you know how much R&M has been achieved?

How do you assess fielded systems?

How do you plan and manage an R&M program?

How do you account for differences in fielded R&M versus demonstrated R&M?

10.3.2 RAM Definitions

10.3.2.1 Reliability**.** Reliability is the probability that an item will perform its intended function for a specified interval under stated conditions. Simply stated, it is how long the system can work. Mean Time Between Failure (MTBF) is commonly used to define the total functioning life of a population of an item during a specific measurement interval divided by the failures during that interval. The failure rate (Greek letter lambda) is defined as the number of item failures of per measure of unit life. Sometimes people in the program office erroneously use MTBF and failure rate interchangeably.

- Failure rate can be calculated as follows:

  Failure rate = 1/MTBF (failures over time)

  (Failure rates of components in series are additive)

- Characteristics of failure:
  - Types of failure include:
    - stress/strength (bar in tension),
    - damage/endurance (corrosion/wear/fatigue),
    - challenge/response (emergency brake/S/W program), and
    - tolerance/requirement (copier machine/measuring instrument).

– Probability of success (confidence interval; confidence level)
– Prediction (subject to much disagreement)

10.3.2.2 Mission Reliability. Mission reliability is the probability that a system will perform mission-essential functions for a period of time under the conditions stated in the mission profile. Measures of mission reliability include only those incidents affecting mission accomplishment.

10.3.2.3 Logistics Reliability. Logistics reliability is the probability that no corrective maintenance or unscheduled supply demand will occur following the completion of a specific mission profile.

10.3.2.4 Maintainability. Maintainability is the probability that if prescribed procedures and resources are used, an item will be retained in, or restored to, a specific condition within a given period. It is the inherent characteristic of a finished design that determines the amount of maintenance required to retain or restore the system into a specified condition. Corrective maintenance can be measured by Mean Time to Repair (MTTR); or, stated in more simple terms, how quickly and easily the system can be fixed. Also, Mean Maintenance Time (MMT) not only includes corrective maintenance but also accounts for preventive maintenance.

10.3.2.5 Availability. Availability is based on the question, "Is the equipment available in a working condition when it is needed?" Availability is defined as the probability that an item is in an operable and commitable state at the start of a mission when the mission is called for at a random point in time. The user is most concerned about this parameter. This reflects the readiness of the system. There are a number of definitions of availability, and it is important to understand the basic ones. All are based on this standard mathematical relationship, with differing definitions of the terms "Up Time;" "Down Time;" and "Total Time":

$$\text{Availability} = A = \frac{\text{Up Time}}{\text{Total Time}} = \frac{\text{Up Time}}{\text{Up Time + Down Time}}$$

One measure in particular, Operational Availability (Ao), covers all time segments the equipment is intended to be operational. As seen by the following equation, operational availability is based on a mathematical relationship among three characteristics: reliability, maintainability, and the effectiveness of the logistics support system. Reliability is measured as the mean operating time plus mean standby time in an operational condition (represented by Mean Time Between Maintenance (MTBM)). Maintainability includes the mean maintenance time for both corrective and preventive actions (represented by Mean Maintenance Time (MMT)). Logistics support effectiveness is the combination of the logistics delay time plus any administrative delays (represented by Mean Logistics Down Time (MLDT)). The Mean Time Between Maintenance (MTBM) is based on all maintenance actions, whether corrective or preventative in nature. (See the Maintainability Section at 10.5.)

$$A_o = \frac{MTBM}{MTBM + MMT + MLDT}$$

Note: There are a number of program support contracts that require the contractor to meet an A_o requirement. You can see that the contractor would want to control the support structure or have it precisely defined before signing up for A_o.

Another measure, Inherent Availability (Ai), is a measure of the system availability with respect only to operating time and corrective maintenance. Under these idealized conditions, the time involved in preventive maintenance; the delay times associated with all types of maintenance actions; and administrative delays are ignored. Because only unscheduled maintenance actions are considered in this definition, the mean operating time is defined as the Mean Time Between Failure (MTBF).

$$A_i = \frac{MTBF}{MTBF + MTTR}$$

Inherent availability is useful in determining basic system operational characteristics under conditions which might include testing in a contractor's facility or other controlled test environment. Likewise, inherent availability becomes a useful term to describe combined reliability and maintainability characteristics. Inherent availability is also used to define one characteristic in terms of the other during early conceptual phases of a program when, generally, these terms cannot be defined individually. Since this definition of availability is easily measured, it is frequently used as a contract-specified requirement. It is not a good definition to use when estimating the true combat potential for most systems because it provides no indication of the time required to obtain required field support. This term should normally not be used to support an operational assessment.

A third measure, Achieved Availability (Aa), is frequently used during development testing and initial production testing, when the system is not operating in its intended support environment. It is defined over a specific period of time and relates the time the equipment is in use, i.e., operating time (OT), to the sum of the OT plus the corrective maintenance time (TCM) plus the preventive maintenance time (TPM).

$$A_a = \frac{OT}{OT + TCM + TPM}$$

Achieved availability is much more a system hardware-oriented measure than is operational availability, which considers operating environment factors. It is, however, dependent on the preventive maintenance policy, which is greatly influenced by nonhardware considerations.

To summarize, operational availability is the most desirable form of availability to be used in helping assess a system's potential under fielded conditions. Achieved availability and, to a lesser degree, inherent availability are primarily the concern of the developing organization in its interface with the contractor.

10.3.3 RAM Has Many Other Terms

The terminology used is not standard and tends to depend on the Service and/or system. Be sure you have a clear idea of what the RAM terms mean in the requirements documents and the contract specification. The American Society for Quality Control published a 361-page book entitled, *Reliability, Availability, and Maintainability (RAM) Dictionary*, by Tracy Omdahl. This is the "Webster's Dictionary" of RAM terms.

> The metrics used in most engineering technologies tend to be natural phenomena such as speed, rate of turn and payload. While they may require very careful definition and control of the way they are measured, the metrics themselves are not subject to different definitions...
>
> RMS (reliability, maintainability, and supportability) however, uses metrics that are somewhat specialized rather than naturally defined. As a result, there are more than 2000 terms defined in documents reviewed so far, many of which have the same meaning but different definitions.
>
> Society of Automotive Engineers *RMS Newsletter*, Apr 1990

10.3.4 RAM Requirements and Terms

10.3.4.1 <u>RAM in the User's Requirements Documentation</u>.

10.3.4.1.1 Mission Need Statement (MNS)

The MNS provides the information listed below:

- identifies mission need or deficiency in general terms (not the solution) and
- establishes very general system constraints including logistics (five pages only).

10.3.4.1.2 Assessment of Alternatives (AOA)

The AOA describes the following information:

- trade studies performed during the Concept Exploration phase,
- alternative solutions, which balance effectiveness (lethality, deployability, availability, and dependability) and affordability (costs for deployment, production, operations, and support), and
- best solution identification.

10.3.4.1.3 Operational Requirements Document (ORD)

In the ORD, the following items are included:

- solution-oriented focus on the preferred solution selected following the AOA, and
- user definition of system RAM parameters in operational terms.

10.3.4.2 Measures of Systems Readiness. The "user" or "operator" has various measures highlighted in the ORD that must be translated by the program office into specifications. Here is a sample of user measurements compared to the MTBF (reliability) and MTTR (maintainability) often used in contractual specifications:

OBJECTIVE AREA	RELIABILITY (MTBF)	MAINTAINABILITY (MTTR)
- - - - - - - - Operational Effectiveness - - - - - - - -		
Increase Readiness	Mean Time Between Downing Events (MTBDE)	Mean Time to Restore System (MTTRS)
Increase Mission Success	Mean Time Between Critical Failures (MTBCF)	Mean Time to Restore Functions (MTTRF)
- - - - - - - - Ownership Costs - - - - - - - -		
Decrease Maintenance Personnel Costs	Mean Time Between Maintenance Actions (MTBMA)	Mean Labor Hours Per Maint. Actions MMH/MA
Decrease Logistics Support Costs	Mean Time Between Removals (MTBR)	Parts Costs/Removal

We can now see the connection between the two goals of a good RAM program (higher operational effectiveness and lower ownership costs), the users' ORD measurements, and the contractual measurements (MTBF or MTTR in this case). Remember, the developmental testers test to contractual specifications; and the operational testers test to the ORD thresholds. The operational user, the program offices, and the contractor often get very confused over the process of translating ORD numbers to contract specs and vice versa.

10.3.4.3 Contractual Terms – MTBF. The contract must be specific! The user, the program office, and the contractor must understand and agree not only to the RAM terms in both the ORD and specification but also to the definition of "failure" to be used in the contractual specification. When test results are compiled, the user sometimes misunderstands the meaning of the results relative to the ORD thresholds set forth.

Example: *What counts for a contractual definition of "failure?"*

As a technique, the following can be used. Failure categories: All events occurring during reliability tests are classified as relevant or nonrelevant. Relevant failures are further classified as chargeable or nonchargeable. Make sure that failure classifications are defined on the contract and that the contractor, user, and System Program Office (SPO) meet and agree on these terms early in the process.

Examples of contractually chargeable, relevant events:

- failures due to equipment or part design,
- failures due to manufacturing defects in equipment or parts,
- intermittent events, and
- unverified failures (can not duplicate).

Examples of nonchargeable and/or nonrelevant events:

- installation damage,
- accident,
- mishandling,
- normal operating adjustments,
- events caused by human error, and
- software errors corrected and verified in subsequent testing.

It's easy to see the problems a program manager can face when test results return with many failures reported. But are they failures? Do you want lawyers to determine the definition?

10.3.5 R&M Allocation

The operational user requirements and goals are generally at the system level. These need to translate customer system requirements to lower levels of assembly:

- subsystem,
- line replaceable unit (LRU),
- shop replaceable unit (SRU),
- individual components,
- allocation (shows relationship between individual items and whole system), and
- design target for engineers.

Method 1 – For known equipment in a new application, for example, we would allocate 100 hours MTBF, using F-16 radar with 50 hours MTBF in the F-22 and expecting 50 percent of the environmental stresses in the F-22.

Method 2 – When using a weighted model and expected parts count, the more parts to a subsystem, the more failures are allocated to that subsystem.

Example: Having 3 subsystems with a total parts count of 1000 and with the #3 subsystem having 400 parts or 40 percent of the total, we would allocate to #3 using the following formula: (failure rate) X (.4) = allocation for subsystem #3.

IMPORTANT: Comparative, allocated, predicted, and measured (test results) values are used in the design process. These values impact personnel, planning, support equipment requirements, etc., throughout the system design process. Generally, allocated values are used as the basis for reliability requirements in subcontractor and vendor specifications.

10.4 RELIABILITY TECHNIQUES

10.4.1 Contracting for Reliability

10.4.1.1 Requirements. To attain an increase in combat capability, operational thresholds and goals, these requirements must be communicated in clear operational terms. Then, these operational terms must be properly translated into viable contractual terms understood and accepted by the user, program office, and the contractor. The following items are important to remember:

- requirements must be clear;
- simple design requirements should make a system cheaper to produce, operate, and maintain; and
- requirements should be testable.

10.4.1.2 Source Selection. Source selection is the most important contractor motivational factor. In a source selection for a new or modified system, RAM must be singled out as specific evaluation criteria.

10.4.1.3 Incentives and Warranties. Incentives reward contractors for exceeding minimum program requirements. Warranties hold contractors responsible for sustaining, in the operational environment, the performance levels for which incentives have been paid. Try a fixed-price warranty repair contract with a warranty period of three to five years – long enough for the contractor to demonstrate compliance. If the system does not meet the warranted level, consignment spares should be included to maintain combat capability while repairs and engineering improvements are made. Additionally, the matrix in Table 10A, taken from the *Flexible Sustainment Guide,* January 1997, gives an idea of the impact that reliability has in selecting from a multitude of warranty types.

TABLE 10A
WARRANTY CONSIDERATION MATRIX

	WARRANTY TYPE																
CONDITION	RIW	R&MIW	T&RIG	MTBF-VT	AG	LSCG	WOS	CLR	MPC	SPL	R&MW	CRW	RW	UFG	UL	CSL	R&EA
Spare Reliability exceeds system life			X	X	?		X	X	X	X	X	X		X	X	X	X
Spare Reliability exceeds technology cycle			X	X	?		X	X	X	X	X	X		X	?	?	X
Spare Costs less than repair			X	X	?		X	X	X	X	X	X		X	X	X	X
Competitive Commercial Repair	?	?	X				X										X
Contract repair (costs less than organic	X	X	X	X	?	?	X		X				X				X
Repair Organic less									X				X				

WARRANTY LEGEND

RIW	Reliability Improvement Warranty	SPL	Spare Parts Level Warranty
R&MIW	Reliability & Maint. Improvement Warranty	R&MW	Reliability & Maintainability Warranty
T&RIG	Test & Repair Improvements Guarantee	CRW	Component Reliability Warranty
MTBF-VT	Mean Time Between Failures-Verification	RW	Reliability Warranty
AG	Availability Guarantee	UFG	Utility Functions Guarantee
LSCG	Logistics Support Costs Guarantee	UL	Ultimate Life Warranty
WOS	Warranty of Supplies	CSL	Commercial Service Life Warranty
CLR	Chronic LRU Guarantee	R&EA	Repair and Exchange Agreements
MPC	Maximum Parts Cost Guarantee		

10.4.1.4 <u>Tools</u>. Section 17.5 of this Guide describes two contract-related tools, LOGPARS and Turbo Streamliner. Each tool has sections devoted to Request for Proposal (RFP) construction, including RAM references. Website addresses for these tools are provided in Section 17.5.

10.4.2 Predesign: Research and Analysis

Accurately define mission, environmental, and real-life profiles, including the following:

- consider past experiences with field operations and lessons learned;
- define equipment environment (fuel, oil, static electricity); and
- define natural environment (solar, humidity, salt, etc.).

10.4.2.1 Example 1: Natural Environment. A relative humidity of approximately 35 percent is normal for electronics. More humidity causes corrosion and less humidity causes static electricity problems. The Royal Air Force performed experiments with dehumidification units. The tests showed a 22 percent reduction in avionics servicing for both the F-4 Phantom and the Tornado and an 18 percent in the Nimrod. When these tests were reported in the *CODERM Newsletter*, September 1993, another result was noted, " Added bonus... the cabin of the Nimrod no longer smells like a wet dog in a duffel coat."

10.4.2.2 Example 2: Transportation and Storage. Maverick missiles were placed in storage containers and transported by ship to the Mid East. These containers were not inspected upon delivery, and the units were placed in desert open-air storage. One year later, the containers were opened; and they contained 6-8 inches of salt water! The fiberglass containers did not seal properly and the plugs had blown out in shipment.

10.4.2.3 Tool. Sometimes, part of the disparity between laboratory test results for reliability and initial operations test results can be a problem with packaging. At the following address this office will do the packaging engineering for you!

ASC/YHC
Eglin AFB, FL 32542-5000
DSN 872-4609
(904) 882-3779

10.4.3 Design Process

The steps in the design process include:

- performing trade studies;
- performing system and item analyses of the candidate design;
- establishing design criteria; and
- making detailed decisions that transform requirements, resources, and constraints into a design.

10.4.4 RAM Analyses

Four of the more common techniques used in RAM analyses are:

- reliability prediction methods;
- failure mode, effects, and criticality analysis;
- maintainability analysis; and
- reliability centered analysis.

10.4.4 Tools for Analysis

10.4.4.1 Redundancy. Because of the impact to logistics reliability, the PM's interest should be great if the contractor proposes redundancies to meet mission reliability requirements. Space weight and power provisions must be accounted for. Additionally, logistics support must be included when calculating support requirements and costs.

10.4.4.1.1 Exercise. The initial design for a system has three subsystems (A, B, & C) in series (each must work for the system to be successful). Their respective reliability factors for the components of a series system are shown below:

-----[RA (.95)]------[RB (.90)]-------[RC (.80)]
Reliability of the system = R × Rb × Rc or (.95) × (.90) × (.80) = ???

What if the user requirement is .80 for the system? Does the above system meet the requirement? Even without a calculator, we know right away that the system is below .80 since the lowest reliability of a subsystem is .80.

What are the options if you wish to improve the system reliability? What are the risks and/or tradeoffs? What if you choose redundancy?

10.4.4.1.2 Redundancy Characteristics.

When choosing redundancy, there are three major items to consider:

1) The level of redundancy application, e.g., piece part, black box, or complete redundant systems;

2) The redundant element's operating state (Examples: An airport, which is operating two separate ground-control radar units at all times, has active redundancy. Carrying a spare tire in your trunk is passive redundancy.); and

3) The method used to activate the redundant element. (The driver of a car loses mission time changing a flat tire. An electronic switching network senses a failure and automatically switches without loss of mission time.)

10.4.4.3.3 Redundancy Summary

- Redundancy can help improve mission reliability.
- Redundancy generally decreases logistics reliability and increases support costs.
- Try to improve the reliability of a single unit whenever possible; use redundancy as a last option.

10.4.4.2 Failure Modes, Effects, and Criticality Analysis (FMECA). FMECA is a procedure that analyzes each potential system failure mode to determine its results or effects on the system and to classify each potential failure mode according to its severity. The purpose is to provide a safer, more reliable initial design. See Figure 10-2. MIL-STD 1629A is being rewritten to become a Society of Automotive Engineers standard. Ford Motor Company uses the FMECA procedure but uses a different criticality methodology. Sometimes logisticians and systems engineers wish to perform an FMECA down to the piece part; this can be very expensive and is not always needed. The FMECA also helps to identify single points of failure that show how the failure of one component can cause the failure of the whole system. Single points of failure must be identified and eliminated during the design process. To provide a better understanding of a typical analysis, a sample page from a FMECA is presented in Figure 10-3.

10.4.4.2.1 Steps in the FMECA Process:

- What is the function of the system? How does it work?
  - parts?
  - interfaces?
  - software?

- How many ways can it malfunction?

- What happens if an item malfunctions?
  - to the next higher assemblies?
  - system?
  - What is the risk?
  - how critical is each malfunction?
  - what is probability that it can happen?

**FAILURE MODES, EFFECTS
AND CRITICALITY ANALYSIS (FMECA)**

- **Definition:**
  - a review that examines potential failure modes to determine their effects on equipment
  - employs a “bottoms-up” approach

- **Uses:**
  - shows areas that need corrective action
  - ranks severity of failures/safety
  - identifies reliability-critical components
  - provides input data to systems engineering/logistics

Figure 10-2: Failure Modes, Effects, and Criticality Analysis

SYSTEM NAME	SUBSYSTEM NAME	COMPONENT NAME AND PART NO.	COMPONENT FUNCTION
SPACE SHUTTLE MP SRM 10-00	SRM CASE 10-06	CASE ASSEMBLY, FORWARD 10-05-01 SEGMENT 1U50147-08	
AUTHOR AND COMPANY W. L. HANKINE THIOKOL CORPORATION	**DATE** **JUNE 1983**	**REVISION**	

MISSION PHASE	COMPONENT FAILURE MODE AFFECTED COMPONENT REASONS FOR FAILURE	FAILURE EFFECT ON A. SUBSYSTEM FUNCTION B. SYSTEM FUNCTION C. MISSION D. VEHICLE AND PERSONNEL	CRITICALITY CATEGORY	CONTROL METHODS TO INSURE A RELIABLE PRODUCT
	<u>ASSEMBLY JOINTS LEAK.</u> <u>PART NO.</u> — <u>PART NAME</u> — <u>QUANTITY PER COMPONENT</u> 1U50131-09 CASE SEGMENT, CYLINDER 2 1U51473-01 CASE SEGMENT, FORWARD 1 1U50228-24 PACKING (O-RINGS) 2/JOINT 1U100269-01 TEST PLUG 1/JOINT 1U50228-15 PACKING (TEST PLUG) 1/PLUG	A. HIGH TEMPERATURE GAS FLOW WILL CAUSE METAL EROSION AND PROBABLE BURNTHROUGH AND CASE BURST. B. CATASTROPHIC FAILURE OF SRM. C. MISSION LOSS. D. ***VEHICLE AND PERSONNEL LOSS.***	1	SEE CIL
	1. TANG-A-DIAMETER EXCEEDS UPPER LIMIT OR SURFACE FINISH NONCONFORMING, OR IS GOUGED ACROSS BOTH SEAL SURFACES.		(1)	1. TRAINED, QUALIFIED MACHINIST TO PERFORM MACHINING OPERATION. 2. SPECIAL PROFILE TEMPLATE TO CONTROL LATHE CUTTING HEAD. 3. 100% INSPECTION OF TANG-DIAMETER, CLEVIS, DIMEN - SIONS AND O-RING GROOVES USING PI TAPE AND STAND-DARD MEASURING INSTRU- MENTS . SURFACE FINISH SAMPLE INSPECTED BY SURF-INDICATOR.
	2. CLEVIS NONCONFORMING (DIAMETER, THICKNESS, FINISH).		(1R)	
	3. CLEVIS O-RING GROOVES EXCEED WIDTH AND/OR DEPTH UPPER LIMITS OR CORRODED.		(1R)	
	4. 0-RINGS NONCONFORMING OR DAMAGED DURING ASSEM-BLY.		(1R)	
	5. LEAK CHECK PLUG LOOSE OR WITHOUT O-RING, INNERMOST SEAL INEFFECTIVE PER 1 ABOVE OR THE CONDITIONS OF O-RING ARE PER 4 ABOVE.		(1)	
	6. ***FOREIGN MATERIAL IN O-RING GROOVES.***		(1R)	
	7. IGNITER FLANGE NONCONFORMING, FLATNESS FINISH.		(1R)	7. A. TRAINED, QUALIFIED MACHINIST TO PERFORM MACHINING OPERATION. B. 100% INSPECTION OF IGNITER FLANGE FLATNESS BY TIR READOUT FINISH IS SAMPLE INSPECTED USING SURF-INDICATOR.
	8. CASE ASSEMBLY JOINT ROTATION CAUSES LIFT-OFF FROM SECONDARY O-RING (PRIMARY O-RING WILL REMAIN IN COMPRESSION).		(1R)	
	9. EXPANSION OF CLEVIS GAP BECAUSE OF RESIDUAL STRAINS RESULTING FROM MANUFACTURING PROCESSES.		(1R)	
				PAGE OF

Figure 10-3: Sample Page, Failure Modes, Effects, and Criticality Analysis

10.4.4.2.2 Benefits of FMECA:

- less initial redesign
- less test-analyze and fix
- more likely to meet schedule and cost goals
- greater customer satisfaction
  – lower warranty claims
  – fewer liability claims (Lawyers)

10.4.5 Reliability Design for Electronics

Generally, reliability prediction techniques have been based upon empirical models derived from field data found in both military and commercial handbooks. In the next section, you will see some of the problems involved and hear about an alternative called Physics of Failure (POF). Also, the FMECA and redundancy are used in designing electronic systems. Additional tools, such as a parts control program and electronics derating, are also used to improve the reliability for electronic systems.

10.4.5.1 <u>Parts Control Program</u>. A large percentage of hardware is unreliable due to purchased parts. Many may be immature, less reliable, not tested/qualified for your application. The purpose of a parts control program is to assist in selection and use of parts in new/modified equipment. A parts control program enhances standardization, interchangeability, reliability, and maintainability. It will also conserve scarce resources you would need to develop components. The quality of the parts is a factor in predicting the reliability of the electronic components up to system level. Currently handbooks are used in prediction methodology and are currently under tremendous criticism. Handbooks such as MIL-HDBK-217F use field data in their methodology. The results are controversial. Proponents believe, as a minimum, the results allow for quick comparisons to be made. (MIL-HDBK-217F is to be retained as a handbook until the Institute of Electrical and Electronic Engineers (IEEE) or a similar organization develops a suitable replacement.)

10.4.5.2 Tools. The Military Parts Control Advisory Group (MPCAG) operates an on-line parts database, prepares standardized part design documentation, and tests parts to qualify vendors. (The qualifying vendors program is currently under scrutiny.) Four Defense Logistics Agency (DLA) organizations can help with parts control:

- Defense Electronic Supply Center (DESC/EPA), Dayton, OH
  (513) 296-5431
  Tubes, resistors, capacitors, semiconductors, relays, and fiber optics.

- Defense Industrial Supply Center (DISC/ESM), Philadelphia, PA
  (215) 697-4395/3007
  Fasteners, seals, springs, and bearings

- Defense General Supply Center (DGSC/SEA), Richmond, VA
  (804) 275-4885
  Refrigeration components, lamps, electrical hardware, lubricants, batteries etc.

- Defense Construction Supply Center (DCSC/SSI), Columbus, OH
  (614) 236-2205/2886
  Gears, pulleys, belts, hoses, tubing, valves, etc.

10.4.5.3 Parts Derating. Derating establishes a design margin to provide the robustness necessary in the operational environment. Derating is the practice of limiting mechanical, thermal, and electrical stresses on components to enhance reliability; it also increases the reliability of individual components and thereby the reliability of the system. Derating is always a compromise among weight, size, cost, and failure rate. Procedures vary with different components when using derating. Microcircuits are derated as a function of operating junction temperature. Mechanical parts are derated in terms of tension, torsion, temperature, and other limits.

CAUTION: "Cookbook" derating criteria generally do not allow you to quantify the magnitude of reliability improvement.

10.4.5.4 Reliability Prediction. Prediction Methods include the following:

- parametric estimations, e.g., failure rate as a function of weight of avionics,
- engineering models, and
- models that are based upon historical reliability data (handouts).

How accurate are the values when a manufacturer states that a transceiver has a "MTBF greater than 7000 hours"? How did the manufacturer come up with the value? These are some of the questions commercial and military program offices have been struggling with for years. MIL-HDBK 217 accounts for stress, environment, and quality as factors for predicting reliability.

10.4.5.4.1 Example: The failure rates for a hypothetical circuit board were predicted using various failure rate models. (Source: *1986 RAMS Proceedings*, p. 162). For the same device (14 components), the following were predicted failures per million operating hours:

Model	**Predicted Failures Per Million Hours**
Bell Communications Research	12,502
MIL-HDBK-217	715,784
British Telecom	1,258
CNET (French)	16,714
Nippon Telephone and Telegraph	9,525

NOTE: "MIL-HDBK 217 is not intended to predict field reliability and, in general, does not do a very good job in an absolute sense. The reasons for this are numerous including different failure definitions for field problems that MIL-HDBK-217 does not account for..."

RAC Technical Brief
April 1990

10.4.5.5 Comparative Analysis. Comparative analysis is a method for predicting the operational reliability or maintainability characteristics of systems yet to be fielded. Using this method, engineers do the following:

- break down the system into subsystems and identify the most comparable subsystems from other similar systems,

- extract field data on existing systems,

- combine engineering factors and field data,

- compare predicated v. actual operating environments, and

- compare predicted v. actual operating environments.

Example. F-22 flight controls would use a combination of F-15 and F-16 flight controls as a baseline. Engineers determine that the electrical components would have a two- to five-fold factor improvement in the F-22. Since F-15 and F-16 field data has a Mean Time Between Maintenance inherent (MTBMi) of 70 hours, engineers would predict 140 to 350 hours MTBMi for the electrical components of the F-22 flight control system.

Bottom Line: The prediction process today is not ideal. Comparative methods are better than handbooks at present. This data, some of it bad, some of it good, finds its way into the support analyses with resultant problems during initial fielding.

10.4.5.6 Physics of Failure (POF). This method holds much greater promise than the old handbook method. One drawback of POF is the time it takes to perform the analysis. The following are quotes and excerpts from Michael W. Deckert article, "Physics of Failure: A Science Based Approach to Ultra High Reliability," *Program Manager*, Sept.-Oct. 1994:

> "Key trade-offs between commercial and military specification components, ruggedized vs. nonruggedized boards, emerging vs. traditional technology, and design layout occur early in a program and can significantly impact the reliability and life-cycle costs of a system. The POF modeling and simulation tools provide program managers and system designers with a science and engineering based approach for evaluating these types of trade-offs that can impact a program."

The POF approach uses modeling and simulation techniques to identify first-order failure mechanisms prior to physical testing. In addition, the POF approach scientifically evaluates new materials, structures, and technologies by designing tests, screens, safety factors, and accelerated simulation.

10.4.5.6.1 Impacts of the POF are listed below:

- POF tools can be used to determine failure mechanisms and assist in accelerated test design.

- POF concepts can improve depot maintenance in three areas: failure verification and isolation, improved reliability after repair, and improved repair verification.

- Currently, unfailed electronic components are assumed to be "as good as new" if they have not failed. With POF, a more reliability centered maintenance approach would be possible, e.g., timed change of a circuit card assembly before actual failure.

- Using the POF, an Environmental Stress Screening (ESS) could be more accurately designed to determine how much useful life remains after the screening is performed.

- Currently the FMECA assumes that integrated circuits are failed, either opened or closed. The FMECA method does not account for intermittent failures. Using the POF method's automated assessment tools, failure times, sites, and stress drivers for the key failure mechanisms can be determined.

10.4.5.6.2 POF software tools. The POF computer tools can reduce the number of hardware tests by improving the design during the Pre-Milestone 0 through Milestone II phases of the acquisition life cycle. In the past, reliability growth programs began after test on hardware was conducted in later phases.

The University of Maryland developed CADMP-2; it is used to assess the reliability of integrated circuit, hybrid and multi-chip module packages.

The University of Maryland developed CALCE; it is a set of integrated tools for the design and analysis of electronic assemblies.

10.4.5.6.3 Other RAM Tools. The Government-Industry Data Exchange Program (GIDEP) is a cooperative activity between government (including the Canadian Department of Defense) and industry participants seeking to reduce or eliminate costs from non-conforming products. With GIDEP, design engineers find a source of qualified parts information. Production engineers find new and innovative techniques to improve production processes and reduce production costs. Reliability engineers use the failure mode and failure rate information during their modeling and assessment studies. Logisticians use mean repair time data in projecting logistics support and resupply requirements. If you want to join the GIDEP, use the following information:

GIDEP Operations Center
PO Box 8000
Corona, CA 91718-8000
DSN: 933-4677
FAX: (909) 273-5200

10.4.6 R&M Testing

10.4.6.1 Test, Analyze, Fix, and Test (TAFT). TAFT is a disciplined process for systematically detecting and eliminating design weaknesses while simulating the operational environment. A closed loop process, TAFT is used to detect failures, feed back data, analyze, redesign, test, and verify fixes. TAFT should start with the first article available and continue until requirements are achieved.

10.4.6.2 Failure Reporting, Analysis and Corrective Action System (FRACAS). FRACAS is a disciplined and aggressive closed-looped reporting system that is an essential part of the TAFT process. With FRACAS, failures and faults of both hardware and software are formally reported. Using this system, analysis is performed to determine failure cause and positive corrective actions are identified, implemented, and verified to prevent further recurrence. Early implementation of FRACAS has the following advantages:

- cost and schedule savings,
- time to assess corrective actions, and
- time to address all failures prior to full-rate production.

10.4.6.3 Environmental Stress Screening (ESS). ESS stimulates assemblies with thermal cycling and random vibration (as a minimum) to precipitate these defects in the developmental facility or the factory. A proper ESS program will be applied early in the design and development phases rather than in the later production phase. An effective ESS program precipitates defects to failure at the lowest level of assembly and does not damage equipment. (A common goal is to use a maximum of 10 percent of component life to conduct ESS.) By moving detection of early failures from the field to the factory, great savings can be attained. Applied early, ESS can pay for itself by correcting defects and by preparing the item under test for subsequent reliability development testing.

10.4.6.4 Reliability Development Test (RDT). The heart of the TAFT process is the formal RDT. The RDT is designed to expose the equipment to thousands of operational use cycles; corrective actions are incorporated and verified during the test. ***Considerable*** *expense and resources are required for the RDT effort*. With proper emphasis on design fundamentals (see the POF section), parts control, and reducing variability during manufacturing, the expensive RDT process will not be overwhelmed with failures that should have been eliminated earlier. Suggestions on conducting a Reliability Testing Program are found in MIL-HDBK-781A, 1 April 1996. However, the standards committee is requesting assistance in locating or developing a suitable industry standard.

10.4.6.4.1 Example. It is estimated that typical costs to detect and remove defects in the field are $15,000. In the factory, estimated costs to detect and remove defects are $1,500 at the system level, $500 at the LRU level, $50 at the circuit card, and approximately $1 at the piece part level.

10.4.6.4.2 Tool. The Reliability Toolkit: *Commercial Practices*, 1995 Edition, is an excellent source for reliability terms, definitions, and engineering processes, such as requirements definition, analysis, design, and testing. For $25, you can get a copy by calling DSN 587- 2608 or by writing to:

Systems Reliability Division
Rome Laboratory
Air Force Material Command
525 Brooks Road
Griffiss AFB, NY 13441-4505

10.4.6.5 Manufacturing RAM Problems. Premature field-system failures are often caused by parts or manufacturing defects introduced during production and repair. Many of the latent defects that result from production errors and weak piece parts can and should be eliminated during production.

10.5 MAINTAINABILITY

Maintainability and reliability are the two major system characteristics that combine to form the commonly used effectiveness index – availability. It is important when we consider that up to one-third of the Services' budgets are earmarked for maintenance. Remember that maintainability is a design consideration, and maintenance is a consequence of that design. As discussed previously, there are two maintenance processes – preventive maintenance and corrective maintenance.

10.5.1 Reliability Centered Maintenance (RCM)

The purpose of RCM is to develop a scheduled maintenance program with the goal of increasing system availability by identifying failures or potential failures before they degrade system effectiveness. The original concept of RCM came from the airline industry. RCM uses information from the FMECA to identify items that are the most critical to system availability. The RCM analysis process uses a decision tree as a guide for complete analysis of each significant item. Preventive maintenance tasks are performed on a scheduled, periodic basis to prevent failures while equipment is in operation. Do not confuse this with other maintenance tasks, such as lubrication and adjustments, needed to keep systems in operation. Preventive maintenance tasks can be divided into two categories: scheduled inspections and scheduled removals.

10.5.1.1 Example:

- Scheduled inspection: Your automobile should be inspected every 15,000; 30,000; and 50,000 miles according to the owner's manual.

- Scheduled removal: The timing belt on your automobile should be removed after 50,000 miles according to your owner's manual.

10.5.2 Test and Diagnostics

Repair of a failed item begins only after identification of the failure. Test requirements should be matched to readiness requirements from the user and the maintenance concept required for the system. A specification may require 90 percent of equipment failures to be identified at the organizational level of maintenance using Built-In-Test Equipment (BITE), technical manuals, and a certain level of skill by the maintainer. Our need for BITE is driven by operational availability requirements that do not permit the lengthy repair times associated with detecting and isolating failure modes in microcircuits. Fault detection, e.g., the engine service light in your car, and fault isolation, e.g., a fault code telling the auto mechanic that the PCV valve is stuck closed, usually are given values by the user. The impact of inadequate diagnostics is usually manifested in long maintenance delays or, if the Built-In-Test (BIT) is faulty, in many removals with a retest OK at higher levels of maintenance. The following are important BIT/BITE considerations:

- What are the contractual definitions of "failure"? Should the contract consider BIT performance only in regards to "BIT addressable" failures (excluding problems not contractually chargeable), or should the contract consider BIT performance in relation to overall mission reliability?

- What failures can BITE detect?

- Will the BITE isolate failures while the basic system is in the operational mode, or must the system be shut down to permit isolation procedures to be performed?

- How do we measure percentage of false alarms? Was the BIT routine erroneous? Is there an intermittent out-of-tolerance condition somewhere?

- What is the percentage of false removals allowed?

10.5.3 Design

<u>Human systems integration</u> plays a major role in maintainability design. Use of virtual reality to check access and visibility among many factors is becoming more commonplace. Some physical design features affect the speed and ease by which maintenance can be performed. These features and pertinent questions are:

- Accessibility: Can the item be reached easily for repair or adjustments?

- Visibility: Can the item being worked on be seen?

- Testability: Can system faults be detected and isolated to the faulty replaceable assembly level?

- Complexity: How many subsystems are in the system? How many parts are used? Are the parts standard or special purpose? Simple systems tend to be both reliable and maintainable. Simplicity can improve both reliability and maintainability by minimizing parts and interconnections and minimizing the number of common hand tools. (The goal is to have no peculiar support equipment or tools in the field.)

- Standardization and Interchangeability: Can the failed or malfunctioning unit be swapped around or readily replaced by an identical unit with no need for recalibration? Standardization of systems, subsystems, parts, tools, and procedures, with those currently used in the field can lower training costs and risk to readiness, especially during initial fielding of systems.

Besides physical design factors, the frequency of maintenance actions is a major factor in both corrective and preventive maintenance. Reliability can have significant impacts on corrective maintenance; and design features such as self-check-out, reduced lubrication requirements, and self-adjustment would affect the need for preventive maintenance.

10.5.4 Maintainability Demonstration (M-DEMO)

While some elements of maintainability can be assessed individually, a true assessment of system maintainability generally must be developed at the system level under operating conditions and using production configuration hardware. The purpose of an M-Demo is to physically show that the equipment can be maintained. Using the technical manuals, required tools, and other support equipment necessary, the M-Demo is conducted during late Engineering and Manufacturing Development (EMD). Using the actual maintainers and not the contractors is recommended for the M-Demo. MIL-HDBK-471A, *Maintainability Demonstration*, 12 June 1996, outlines suggestions on conducting a demonstration.

10.6 <u>RELIABILITY, MAINTAINABILITY, AND SUPPORTABILITY (RMS) BEST PRACTICES</u>

This section contains a sampling of RMS best practices for the purpose of communicating practices that one or more commercial or military organizations have adopted and reported. Most of the items were gleaned from the Best Manufacturing Practices (BMP) program, a unique industry and government cooperative technology transfer effort. The program maintains a Center of Excellence (BMPCOE) at the University of Maryland. Over 100 participating commercial and military organizations have been surveyed, and best practices validated during the survey are documented in survey reports. The reports are available through the Defense Technical Information Center (DTIC) or by accessing the BMPnet. Requests for recent survey reports or inquiries regarding the BMPnet may be directed to the Best Manufacturing Practices Program (details in the POC/Reference Section 10.6.17).

The examples and tools that follow report some of the RMS best practices that have benefited their users. Hopefully, one or more of them will apply to the reader.

10.6.1 Bar Coding

The sometimes-difficult decision to surrender valuable circuit-board real estate to accommodate board markings has been eased by developing a laser marking method. This method uses bar codes to place part of the serial number on the edges of boards. Not only can the boards be tracked through the manufacturing process using these markings. but also they can be more easily identified among densely packed adjacent boards during servicing of the assembled system. Bar coding is a key tool for the accomplishment of Configuration Management.

Hughes Missile Systems Group, Tucson, AZ

10.6.2 Special Attention to Placement of Maintenance Access Panels (V-22)

Bell-Boeing Vertol

10.6.3 Maintenance Management Software with Graphical User Interface

Now that people are using client/server computing and graphical user interface, the market for maintenance software is growing rapidly and is predicted to top $1 billion by the year 2000.

Metropolitan Atlanta Transit Authority (MARTA)

10.6.4 Automated Test Stations

Lockheed Martin-Government Electronic Systems (LM-GES) uses three AEGIS automated test stations – RF, digital, and analog – for testing various subassemblies. Each test station integrates varied RF, digital, and analog measurements into a single connection for testing ease. The stations allow RF measurements, such as gain, phase, differential phase, and spectrum analysis, to be taken on solid-state transmit/receive modules and RF devices in high volume quantities. The automated test stations use a computer-driven UNIX operating system; and they contain guided probes, which are capable of repeatable measurements needed for high-volume, tight-tolerance requirements. Using these automated test stations, LM-GES can conduct high-speed testing of dynamic and numerous specifications while collecting data at one station. The stations also provide accessibility to data for analysis of individual lot diagnostics for research and development. In addition, the stations provide a production platform for easy conversion to other programs or devices (or maintenance applications).

Lockheed Martin-Government Electronic Systems

10.6.5 Networking to Provide Total Asset Visibility/Integrated Field Service, Etc.

10.6.5.1 <u>Field Service Communications</u>. Litton Applied Technology Division has established a global communications network linking all of its field service representatives throughout the world directly with division headquarters and with each other. The network is low cost but provides some very powerful capabilities. Each field representative has a Zenith laptop PC equipped with a 3-1/2" drive, 20 MB hard disk, communications modem, and a dot-matrix printer. The software includes Wordstar, d-Base, Lotus 1-2-3, Crosstalk, and a graphics package. The representatives communicate via commercial telephone lines and electronic mail through a PC at division headquarters. Although no classified information is transmitted, all data is scrambled to assure privacy.

Litton Applied Technology Division, San Jose, CA

10.6.5.2 Tool Management. With regard to networking for tool management, the successful tool management system has the correct tool available for the operator when it is required. To accomplish this goal, Texas Instruments (TI) is creating a distributed network of tooling databases that supports methods and tooling, inventory control, purchasing, incoming inspection, and tool regrinding. The network links several manufacturing sites located throughout northern Texas and Colorado providing central coordination for cutting-tool management. Previously, each site maintained its own tool database. In addition, TI developed a central database providing all worldwide TI locations real-time access to TI failure analysis data. The Failure Analysis Database (FADB) is one of many central databases available through TI's global network. Centrally located in Dallas, Texas, with remote access to all TI locations, FADB can be accessed from any TI facility in the world. All data are continually online and updated in real time.

Texas Instruments, Dallas, TX

10.6.5.3 Data Integration in an Nondevelopmental Item (NDI) Facility. The Sacramento Manufacturing and Services Division (SMSD) NDI facility was established to perform nondestructive inspection of intact aircraft, aircraft components, and other items requiring inspection such as antenna components and structural members. The items are inspected for flaws, anomalies, defects, corrosion, Foreign Object Damage (FOD), and repair areas. The inspection data on a particular item is electronically captured as images, waveforms, and other data. The data is then converted to a simple visual format and delivered with the item to the repair shop. Until recently these individual, independent inspections have been analyzed separately with no electronic connection between the systems. Joint Continuous Acquisition and Life-Cycle Support (CALS) technology and numerous networked high-powered computers have enabled overlaying the data between the SMSD inspection systems.

Sacramento Manufacturing and Services Division., Sacramento, CA

10.6.6 Utilization of Optical Memory Cards to Enhance Total Asset Tracking and Visibility

The Army and the Defense Logistics Agency are using optical memory cards to track assets through the supply chain from the wholesale level to the retail level.

CASCOM, Ft. Lee, VA

10.6.7 Online Spares Acquisitioning

McDonnell Douglas Aerospace (MDA) (St. Louis) has developed an online spare parts requisitioning capability that enables customers to access and order spare parts automatically through the use of Electronic Data Interchange (EDI). Initial operations address Spare Part Order Administration and EDI transactions for request for quote (840) and response

(843) and are currently operational with the Navy's Aviation Supply Office. Although the present process for online requisitioning is a mixture of both manual and automated methods, these improvements have greatly reduced requisition time from several months to several days. MDA's (St. Louis) benchmarking results in this area indicate that it can expect further improvements and by fully automating the process, reach a cycle time of about two hours.

McDonnell Douglas Aerospace, St. Louis, MO

10.6.8 Use of a specialized Integrated Product Team (IPT) with a mission to tackle reduction of operating and maintenance costs through a series of compatible actions

French engine manufacturer, SNECMA

10.6.9 Enhanced Reliability Through Advanced Electronic Cooling System

In support of the Standard Hardware Acquisition and Reliability Program, the Crane Site – Naval Surface Warfare Center (NSWC) undertook a project to design and demonstrate a lightweight military avionics electronics enclosure called the Advanced Electronics Cooling System (AECS). The AECS is capable of effectively dissipating thermal power almost five times more dense than in existing configurations using Format E Standard Electronic Modules (SEM-E) to meet projected requirements for the year 2000 and beyond.

Crane Division, Naval Surface Warfare Center, Crane, IN

10.6.10 Reliability Modeling Program

Litton DSD Product Effectiveness Department has implemented an active Reliability Modeling Program. Key elements of this program are the Parts Stress Reliability Predictions (PRED) and the Reliability, Maintainability, and Availability (RMA) Modeling programs.

Litton Data Systems Division, Agoura Hills, CA

10.6.11 Modular Design

At Litton Amecom, software engineers are involved from the beginning of system development; thus they can provide input to developing the software requirements for the system. This assures that the software requirement specifications are complete and can be implemented. Advanced tools are used for software development. One of the most powerful of these is an online, structured method for developing system software design requirements. It is a commercial program produced by Yourdon, Incorporated, called Yourdon Engineering Workbench, which runs on a PC. The structured analysis serves as an organizing tool for the designer. It enables linkage between system requirements and design and assures complete and nonredundant designs. The program facilitates rapid system modeling and design modeling and is self-documenting. It provides an efficient method for transferring design specifications to software and hardware designers. The structured approach encourages software component modularity for off-the-shelf availability. They have found that many modules can be used in other applications, which reduces development, schedule, cost, and performance risk. The modeling and simulation features of the program allow verification of algorithms, subsystems, and system designs. It can also be used to do sensitivity and "what if" analyses and to establish the system design-dependent mission effectiveness.

Litton Amecom

10.6.12 Standard Interfaces

Vetronics, the electronics and software that control many armored vehicles systems, have become more numerous and complex. United Defense, L.P., Ground Systems Division (GSD) determined that it needed better methods to control how these systems interacted. The basic problems centered on vehicle operators attempting to manage the individual vetronic systems interaction. New procedures were developed to guide the vetronics development and integration process. The strategy was to keep the designs modular and generic, and to maximize their potential for reuse. This strategy was carried out by using standard military and commercial interface specifications, whenever possible, as well as by using an object-oriented design approach.

United Defense, L.P., Ground Systems Division, Santa Clara, CA

10.6.13 Online Logistics Support Database

The logistics support data is derived from the same database used by design and test engineering. The ITT Avionics Division has implemented an online logistics-support database that can be accessed by manufacturing, design, and logistics groups.

ITT Avionics Division, Clifton, NJ

10.6.14 Interactive Computer-Aided Provisioning System

Phalanx provisioning data was originally manually prepared by the ISEA/Design Agency and manually input into the ship's provisioning system by the Inventory Control Point (ICP) provisioner at the Louisville site of NSWC. Hard copies were transmitted back and forth until all data and fields were validated. Louisville has implemented the Interactive Computer-Aided Provisioning System (ICAPS) to automate Phalanx technical documentation development and submission.

Crane Division, Naval Surface Warfare Center, Crane, IN

10.6.15 Continuous Acquisition and Life-Cycle Support (CALS)

Lockheed Martin and AT&T Federal Systems Advanced Technology have applied the CALS concepts in differing fashions as described in the following subsections.

10.6.15.1 Lockheed Martin. Laboratory systems engineering and laboratory testing have been applied to CALS candidate products at Lockheed Martin-Government Electronics Systems (LM-GES) since 1994. The CALS goal of a Contractor's Integrated Technical Information Service has been promoted since the mid 1980s, but implementations have been scarce. LM-GES established a laboratory to provide a test-bed for products determined to provide CALS-compliant solutions to various requirements. Testing is being performed in the context of a nine-step, systems engineering, life-cycle process focused on CALS-defined inputs and outputs.

Lockheed Martin, Government Electronic Systems, Moorestown, NJ

10.6.15.2 AT&T Federal Systems Advanced Technology (FSAT). The Computer-Aided Acquisition and Logistics Support Development group has adopted: (1) an integrated approach including Total Quality Management (TQM) for continuous process improvement, (2) CALS for automation of technical data, and (3) electronic data interchange for automation of business transactions. Applying this integrated approach has resulted in a paperless environment with reduced costs, lead times, and improved quality. Metrics for cost reduction, cycle-time reduction, and the reduction of the number of iterations per illustration have been developed as well as an increased percentage of graphics images used. For example, this initiative has a projected savings of over $3 million for production of documentation. These figures are based on the number of delivered master pages per year of documentation.

AT&T Federal Systems Advanced Technology, and
Bell Labs (Lucent Technology), Greensboro, NC

10.6.16 ISO 9000 Certified Suppliers

Lockheed Martin Electronics and Missiles has instituted a company-wide best practices program that focuses on the quality of the process as well as the product. The approach provides broad coverage of representative Department of Defense and other customer thrusts such as the Army's Contractor Performance Certification Program (CP)2, the Air Force's Manufacturing Development Initiative, ISO 9000, and agile manufacturing. It incorporates them into 12 best practices; each of the best practices is clearly defined and supported by a vice-president-level executive advocate and a management implementation team.

Lockheed Martin Electronics and Missiles, Orlando, FL

10.6.17 POC/Reference

Best Manufacturing Practices Program, 4321 Hartwick Rd., Suite 400, College Park, MD 20740; telephone: 1-800-789-4267; FAX: 301-403-8180; Internet address: http://www.bmpcoe.org

Automated Lessons Learned Collection and Retrieval System (ALLCARS), Internet address: http://www.afam.wpafb.af.mil/LL_Web/allcars.htm